NAVSEA
INDIAN HEAD
Surface Warfare Center Division

Connections

Research

A JOINT NEWSLETTER OF THE INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER AND THE UNITED STATES NAVAL ACADEMY

Issue 1 Winter 2003

A Meeting of Minds

Research collaborations between the Naval Surface Warfare Center's Indian Head Division (IHDIV, NSWC) and the United States Naval Academy (USNA) are creating a new synergy between two elite Navy organizations in Maryland. IHDIV, NSWC is a national center for energetics research, development, and manufacturing. USNA is an eminent undergraduate college responsible for the education and training of future Navy leaders. The payoffs of cooperative research and educational activities between the two organizations are expected to be both immediate and long-term:

U.S. Naval Academy visitors in March 2001 signing of the memorandum of agreement between USNA and IHDIV. Back row: Dr. Charles Dickinson, Bob Kavetsky, Dr. James Short. Front row: Dr. Reza Malek-Madani, Capt. Marc Siedband, Dr. Joyce Shade, Dr. William Miller. Photo courtesy of IHDIV.

- Joint research between USNA professors and IHDIV, NSWC mathematicians, scientists, and engineers produces benefits in the classroom as midshipmen are exposed to practical insights from research problems being explored at Indian Head. These interactions advance the USNA's effort to promote an environment in which research activities contribute to the educational growth of the midshipmen and the professional growth of the faculty.

- IHDIV, NSWC scientists are exposed to the ideas and research accomplishments of USNA faculty, many of whom are innovators in their respective fields. Shared stipend arrangements allow for the cost-effective use of research talent throughout the two Navy organizations.

Inside

- IHDIV, NSWC scientists communicate to the midshipmen and the USNA faculty their expertise in energetics and their vision of potential energetics solutions for the 21st century warfighter. Midshipmen have opportunities to gain first-hand exposure to the application of Indian Head research to future Navy capabilities. This knowledge may prove beneficial when these future officers confront operational battlefield problems that require technical solutions.

- USNA professors have opportunities to observe a Navy laboratory and to remain current with the state-of-the-art advances and technologies in their disciplines by interacting with Navy experts on problems in energetics, ordnance devices, and components.

- IHDIV, NSWC technical experts deliver lectures at the USNA on state-of-the-art science in energetic systems development, providing a unique academic viewpoint on current technology development.

Research Connections ...

This newsletter will be published periodically to provide information about ongoing and potential research collaborations between Indian Head and the Naval Academy.

This first issue highlights:

- An ongoing research collaboration between a USNA faculty member and IHDIV, NSWC researchers;
- The Academy's Trident Scholar Program, another potential nexus for collaborative research and education.

For more information:

IHDIV, NSWC:
Ms. Lisa Davie, Program Manager of USNA/IH Activities:
301-744-6331; DavieLM@ih.navy.mil
Dr. Suhithi ("Sue") Peiris, Research Liaison: 301-744-4252;
PeirisSM@ih.navy.mil

USNA:
Dr. Reza Malek-Madani, Director of Research and Scholarship:
410-293-2504; research@usna.edu
Dr. Joyce Shade, Deputy Director of Research and Scholarship:
410-293-2509; shade@usna.edu

Combining Strengths and Resources

A Memorandum of Agreement (MOA) between the USNA and IHDIV, NSWC, signed in March 2001, formalized the connections between the two organizations and facilitated integration of the Naval Academy's academic strengths with Indian Head's technical expertise, capabilities, and facilities.

"One of the greatest advantages of these research collaborations, from Indian Head's perspective, is in reaching out to the next generation of Naval officers," says Stephen E. Mitchell, Executive Director of IHDIV, NSWC. "As those officers are one day called upon to enforce the decisions of the American people, they will inevitably rely on the technical community for the tools to make it happen."

"Understanding the complexity of those tools and the years of research and testing that went into them will give our future Naval officers a deeper respect for the Fleet's capabilities and better insight into problems remaining to be solved," adds Mitchell.

Dr. William C. Miller, Academic Dean and Provost at

USNA, agrees. "A lot of the support for the U.S. Navy Fleet happens in the laboratories. Through our collaborations with Indian Head, midshipmen come to appreciate that the solutions to their problems will often be found in Navy laboratories."

Dean Miller's own appreciation for both the Fleet and Navy research capabilities runs deep. He is a 1962 USNA graduate, with a 31-year career as a Surface Warfare Officer. He earned Masters and Ph.D. degrees in electrical engineering from Stanford University. During his Navy career, then Rear Admiral Miller served as Chief of Naval Research and Chief Executive of the Office of Naval Research. One of Miller's desired educational outcomes for the midshipmen is the integration of teaching and research across the Naval Academy curriculum.

Dr. Miller's focus echoes IHDIV, NSWC's emphasis on greater connectivity between the warfighter and the technical community. For that reason, Dr. James M. Short, currently serving as Special Assistant to the Deputy Director, DDR&E, Deputy Undersecretary of Defense for Laboratories and Basic Science, says that he is "thrilled by our collaboration with the Naval Academy. The faculty offers us yet another source of assistance on research problems. Having Naval Academy faculty members knowledgeable and interested in propellant, explosive, and undersea warhead research issues provides another fringe benefit as it exposes future Naval officers to those issues in the classroom." In addition, Dr. Short is the Deputy Director for the Center for Energetic Concepts Development (CECD), based at Indian Head.

Dr. Reza Malek-Madani, USNA Director of Research and Scholarship, also values this cross-fertilization of ideas. "The interaction between the Academy and Indian Head presents an invaluable experience for our faculty — and especially the civilian faculty — by providing them with a first-hand opportunity to explore state-of-the-art Navy research issues. Our faculty's participation in these types of collaborative research projects not only contributes to solutions to the Navy's problems, it plays an important role in our educational process when faculty members share the fruits of these efforts with midshipmen."

Knowledge also contributes to safety, says Dr. Alfred G. Stern, Chief Scientist for Energetic Materials at IHDIV, NSWC. "Unlike any other service, Navy officers and sailors sleep with their ordnance aboard ships. Therefore, it is of the utmost importance for these future warfighters to understand key issues regarding explosive and propellant safety and performance," notes Dr. Stern.

Finally, the research connection dovetails with efforts to develop the energetics work force of the future at Indian Head, providing a continuous source of competence well into the 21st century. According to Robert A. Kavetsky, currently on assignment to the Office of Naval Research, "These

"One of the greatest advantages of these research collaborations, from Indian Head's perspective, is in reaching out to the next generation of Naval officers. As those officers are one day called upon to enforce the decisions of the American people, they will inevitably rely on the technical community for the tools to make it happen."

— Stephen E. Mitchell

collaborations represent another angle on educating our work force to keep Indian Head in the forefront of energetics research and development." Kavetsky is one of the forces behind the cooperative research program.

Opportunities Opening Up

Three research collaborations sanctioned via the MOA are underway, and there is potential for many more. According to Dr. Malek-Madani, "We want to expand the opportunities for interaction between faculty and midshipmen and the researchers at Indian Head."

"One of the directions we are working on is increasing the number of summer internships for our students. We also seek help in identifying energetics-related research topics for our Trident Scholars. These projects, supervised jointly by Academy faculty and Indian Head scientists, offer midshipmen direct opportunities to enhance their educational experience with Navy-relevant activities," says Malek-Madani.

During a four-week summer internship, a rising junior or senior midshipman will work in an Indian Head laboratory, mentored by a Navy investigator on a well-defined research activity. The Academy's Trident Scholar Program provides an opportunity for a limited number of exceptionally capable midshipmen to engage in independent research during their senior year (see page 6 for more details).

Spotlight on Collaborative Research

The Gemini Project

Dr. Tom Mahar
Associate Professor
USNA Mathematics Department

The goal of the Gemini project at IHDIV is to construct accurate models of underwater explosions and to use the results of simulations with these models to improve the design of torpedo warheads. The models consist of fluid and structure codes which exchange information during the calculation. The fluid code solves the equations of motion for the compressible flow of multiple materials (typically, gaseous explosion by-products, water, and air), while the structure code computes the deformation of the target. The calculation of structure deformations is a relatively mature field with proven methods available. Predicting multiple material flows, particularly with regard to interface movement, is a very active area of research and is the focus of current work.

The basic numerical approach used to solve the equations of motion for the fluid is the Godunov method. This method amounts to an application of the underlying conservation laws to fixed regions of space, with a few analytical approximations incorporated into the methodology. Godunov solvers for several versions of the equations of fluid flow have been implemented for this research. Solutions generated using this method for single material flows compare very well with known analytical solutions.

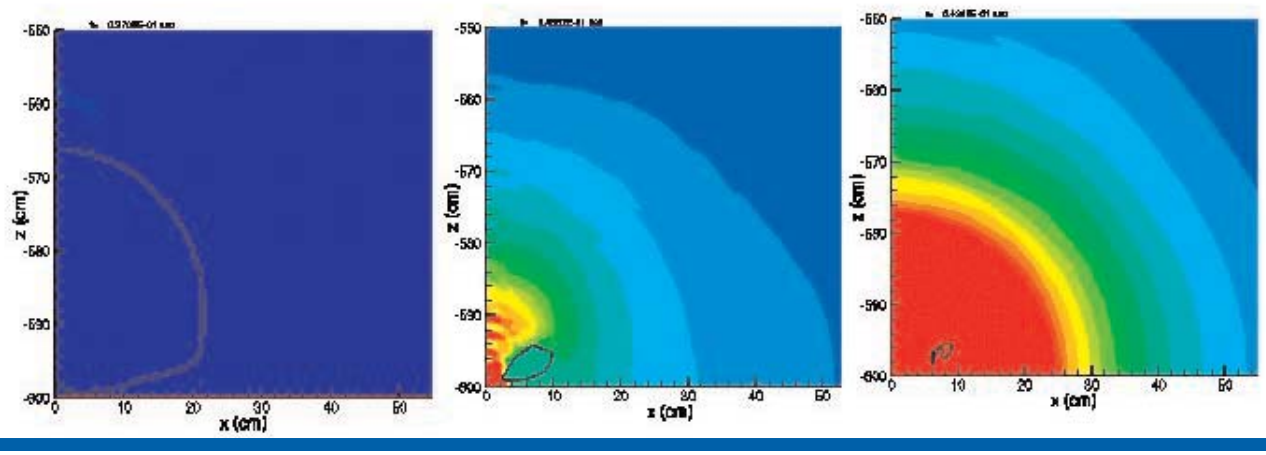
Dr. Tom Mahar (standing) is working with IHDIV, NSWC's Dr. Andrew Wardlaw, Jr., on a project using computers to simulate fluid flow caused by underwater explosions. Photo courtesy of IHDIV.

The conversion of single material solvers to multiple material solvers is accomplished using the Level Set and Ghost Fluid methods. The Level Set method was developed by Sethian and Osher to predict the motion of a material interface. A new dependent variable is introduced whose zero level set is the interface and whose dynamic behavior is passively advected by the flow. The conservation equation for the new variable is added to those for the other fluid variables. The multiple material flow is computed using the Ghost Fluid method, which was developed by Fedkiw and Osher to allow single material solvers to handle multiple material flows. The basic idea is to trade a single flow problem with several materials for several fictitious flow problems of a single material, called a ghost fluid. Since pressure and velocity are continuous for multiple material flows, values for these variables from the multiple material flow are used for each ghost fluid. The discontinuity in the multiple material flow is captured using the entropy variable. Generating values for the entropy variable for the ghost fluids is delicate because entropy is not continuous through a material interface. For one-dimensional problems, constant extrapolation is used. The one material flows of the ghost fluids are advanced in time using Godunov's method and then recombined into a single flow using the Level Set method. This cycle is repeated for as many time steps as required.

The equations of state for the materials occurring in underwater explosions are based on curve fits to experimental data and do not lead to convenient expressions for entropy. One alternate approach for these problems is to copy values for pressure and velocity as above, but to use density to capture the discontinuity. Current work involves testing different implementations of the ghost fluid method and studying other possible approaches.

The goal of the Gemini project at IHDIV is to construct accurate models of underwater explosions and to use the results of simulations with these models to improve the design of torpedo warheads.

For more information, contact Dr. Mahar at tjm@usna.edu.



Pressure isobars from the simulation of the development of a bubble caused by an underwater explosion.

Making Connections: Trident Scholars

The current Chief of Naval Research, Rear Admiral Jay M. Cohen, was a Trident Scholar at the Naval Academy, graduating in 1968. His Trident project was "Conceptual Design and Feasibility Study of Navy Deep Submergence Vehicles."

Submarine, surface warfare, and diver qualified, Admiral Cohen earned a joint Ocean Engineering degree and Master of Science in Marine Engineering and Naval Architecture from the Massachusetts Institute of Technology. As Chief of Naval Research, Admiral Cohen manages the science and technology programs of the Navy and Marine Corps — from basic research through manufacturing technologies.

Admiral Cohen is one of 9 Trident Scholars who have attained the rank of Admiral since the program was instituted at the Naval Academy in 1963. At least 30 Trident Scholars have attained the rank of captain during the same time period. According to the Academy, this prestigious program provides an opportunity for gifted midshipmen to "contribute their thoughts, intuition, creativity, and enthusiasm into a

Exhibit 1
2002 Trident Scholars / Projects / USNA Advisors

Steven R. Burns, Systems Engineering — "Steering Control Compensation of Accelerating Vehicle Motion"
Advisers: Associate Professor Richard T. O'Brien, Jr. and Assistant Professor Jenelle L. Piepmeier

Daniel F. Chiafair, Systems Engineering — "Stability Analysis of a Nonlinear System Stabilizing Controller for an Integrated Power System"
Adviser: Assistant Professor Edwin L. Zivi

Joshua B. Datko, Computer Science — "Supporting Secure, Ad Hoc Joins for Tactical Networks"
Advisers: Assistant Professor Margaret M. McMahon and Associate Professor Donald M. Needham

John D. Dirk, Physics — "Electronic Reliability and the Environmental Thermal Neutron Flux"
Advisers: Professor Martin E. Nelson and Visiting Professor James F. Ziegler

Amanda L. Donges, Quantitative Economics — "A Multinational Empirical Analysis of Humanitarian Assistance"
Advisers: Assistant Professor Matthew J. Baker and Associate Professor Gary O. Fowler

Benjamin A. Drew, Systems Engineering — "Underwater Gliders: Measurement Methods and Analysis"
Adviser: Professor Carl E. Wick

Tarek S. Elmasry, Electrical Engineering — "Characterization of an Optical Self-Homodyne DPSK Receiver"
Advisers: Associate Professor R. Brian Jenkins and Associate Professor Deborah M. Mechtel

substantial, non-textbook problem" during their senior year at the Academy. Trident Scholars work with one or more USNA faculty advisers and may collaborate with other researchers and use equipment at nearby laboratories and facilities.

The Trident Scholar Program fits well with IHDIV, NSWC's efforts to forge closer ties with educational institutions and laboratories throughout Maryland. Says Professor Joyce Shade, Deputy Director of Research and Scholarship at USNA, "We encourage the scientists at Indian Head to suggest research topics, to open their laboratories to our Trident Scholars, and to serve as mentors for their research efforts. These are very bright young people who are committed to excellence and who have a lot to offer to their academic disciplines, to the Navy, and to their country."

For the past few years, an average of 12 senior midshipmen have devoted their time and energies during the academic year to investigate research problems in engineering, mathematics, quantitative economics, and science. When the Trident Scholar appointment is coupled with a summer internship, the student and the mentors can enjoy a focused research experience for 10 to 12 months.

The 2002 winner of the Harry E. Ward Trident Scholar prize, Midshipman Jeremiah J. Wathen, worked with Assistant Professor James J. Butler and collaborated closely with staff

Exhibit 1, cont.
2002 Trident Scholars / Projects / USNA Advisors

Edward H.L. Fong, Computer Science — "Acquisition of 3-D Map Structures for Mobile Robots"
Adviser: Assistant Professor Frederick L. Crabbe, IV

Benjamin M. Heineike, Mathematics — "Modeling Morphogenesis with Reaction-Diffusion Equations Using Galerkin Spectral Methods"
Advisers: Professor Reza Malek-Madani and Associate Professor Sonia M.F. Garcia

Peter D. Huffman, Chemistry — "Towards Improved Optical Limiters"
Adviser: Professor Jeffrey P. Fitzgerald

Pritha M. Mahadevan, Chemistry — "Biophysical Characterization of a Bifunctional Iron Regulating Enzyme"
Adviser: Assistant Professor Virginia F. Smith

Jonathan P. Nelson, Systems Engineering — "Active Control of Fan Noise in Ducts Using Magnetic Bearings"
Advisers: Associate Professor John M. Watkins and Associate Professor George E. Piper

Noah F. Reddell, Electrical Engineering — "Covert Communication Utilizing Discretely Generated Chaos"
Advisers: Associate Professor Erik M. Bollt and CDR Thaddeus B. Welch, III, USN

Jeremiah J. Wathen, Physics — "Optical Limiting Within Capillary Waveguides"
Adviser: Assistant Professor James J. Butler

scientists at the Naval Research Laboratory on his project entitled "Optical Limiting Within Capillary Waveguides." Before pursuing his Navy career in nuclear-powered submarines, Wathen will pursue a graduate degree in physics at the University of Cambridge in England on a Gates Cambridge Scholarship.

Exhibit 1 contains a list of the 2002 Trident Scholars and their projects and advisers. For more information on the Trident Scholars program, contact Professor Joyce E. Shade at 410-293-2509 or shade@usna.edu.

Reconnecting IHDIV, NSWC with the Midshipmen

Opportunities for interaction with recent Naval Academy graduates used to be more abundant, recalls Dr. James Short. "We once brought new Academy graduates awaiting orders to their initial duty station to work with us on explosives and undersea weapons. I recall they had a wonderful time being involved in things like explosive and warhead field testing. While they were having a wonderful time blowing things up for us in their first days following graduation, they were also learning about Naval ordnance. Hopefully, this knowledge came to benefit Indian Head as they progressed through their Naval careers."

As the Navy got smaller, the time between graduation and reporting to an initial duty station was eliminated, notes Dr. Short. "Young ensigns are no longer looking for an interim assignment prior to their first duty station. If, through research collaborations with Naval Academy faculty members, we can impart some knowledge to the midshipmen about ordnance, hopefully we will accrue benefits as the ensigns move up in rank and become decision-makers in the Navy."

Summer internships have emerged as the opportunity of choice to familiarize current midshipmen with Indian Head's work. Scientific and engineering staff at IHDIV, NSWC are invited to advise Lisa Davie (DavieLM@ih.navy.mil; 301-744-6331) of their interest in serving as an intern sponsor, and/or working jointly with USNA faculty advisers, to mentor future Trident Scholars.

Permanent Display in Rickover Hall

To help promote midshipmen's awareness of ongoing energetics research at IHDIV, NSWC, a permanent display was recently completed in the Naval Academy's Rickover Hall. The display highlights Indian Head's technical research and achievements and may be of interest to faculty advisers and midshipmen thinking about research collaborations.